Coupled Thermal-Hydrological-Mechanical Modeling of an *In Situ* Experiment in Fractured Rock

Jonny Rutqvist and Chin-Fu Tsang
Contact: Jonny Rutqvist, 510/486-5432, JRutqvist@lbl.gov

RESEARCH OBJECTIVES

The objective of this work is to increase our understanding of coupled thermal-hydrological-mechanical (THM) processes in unsaturated welded tuff, and to test a numerical simulator used for analysis of coupled THM effects at a proposed future geological nuclear waste repository at Yucca Mountain.

APPROACH

A numerical simulation of coupled multiphase fluid flow, heat transfer, and mechanical deformation was carried out to study the coupled THM processes involved in the Yucca Mountain Drift Scale Test (DST). Coupled THM processes, and the capability of the numerical simulator, TOUGH-FLAC, to model relevant coupled THM processes at the DST, were studied by comparison of numerical results to *in situ* measurements of temperature, water saturation, displacement, and fracture permeability. Of particular relevance in this study are thermally induced rock-mass stress and deformations, with associated changes in fracture aperture and fractured rock permeability.

ACCOMPLISHMENTS

Through the numerical analysis and by comparison to measured THM responses at the DST, an increased understanding of coupled THM processes in unsaturated fractured welded tuff was achieved. The generally good agreement between simulated and measured temperature, displacement, and changes in air permeability (Figure 1) indicated that the numerical model and underlying conceptual model were appropriate for simulating relevant coupled THM processes at the DST. Specifically, thermally induced rock-mass deformation and accompanying changes in fracture permeability were reasonably well predicted using a continuum elastic model, although some individual measurements of displacement and permeability indicated inelastic mechanical responses. It is concluded that fracture closure/opening caused by a change in thermally induced normal stress across fractures is an important mechanism for changes in intrinsic fracture permeability at the DST, whereas fracture shear dilation appears to be less significant. Observed and simulated maximum permeability changes at the DST are within one order of magnitude.

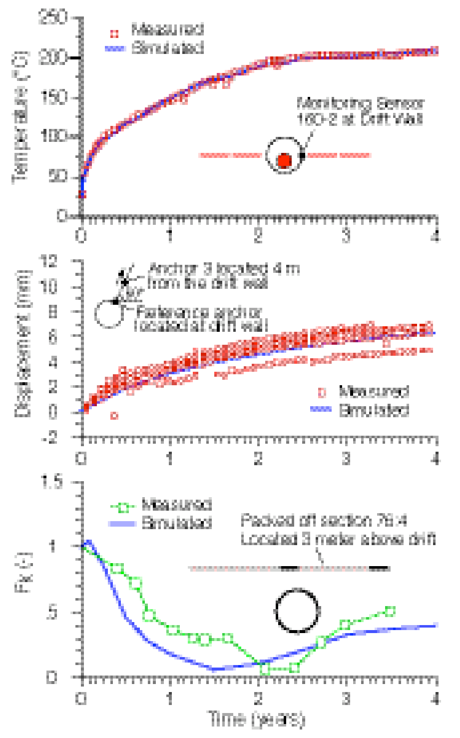

Figure 1. Comparison of simulated and measured temperature, displacement, and permeability change factors (Rutqvist et al., 2005b)

SIGNIFICANCE OF FINDINGS

A solid understanding of the underlying mechanisms for observed THM responses at the DST, including THM-induced changes in permeability, is essential for analysis of THM effects at a future repository at Yucca Mountain. Moreover, the observed and simulated maximum permeability changes at the DST are important information for bounding model predictions of potential changes in rock-mass permeability at a future repository.

RELATED PUBLICATIONS

Rutqvist, J., D. Barr, R. Datta, A. Gens, M. Millard, S. Olivella, C.-F. Tsang, and Y. Tsang, Coupled thermal-hydrological-mechanical analysis of the Yucca Mountain Drift Scale Test—Comparison of field results to predictions of four different models. Int. J. Rock Mech. & Min. Sci (in press), 2005a. Berkeley Lab Report LBNL-56267.

Rutqvist, J., Tsang, C.-F., and Y. Tsang, Analysis of coupled multiphase fluid flow, heat transfer, and mechanical deformation at the Yucca Mountain Drift Scale Test. Proceedings of the 40th U.S. Rock Mechanics Symposium, Anchorage, Alaska, USA, June 25–29, 2005: American Rock Mechanics Association ARMA, Paper No. 893, 2005b. Berkeley Lab Report LBNL-57323.

ACKNOWLEDGMENTS

This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between Bechtel SAIC Company, LLC, and the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab). The support is provided to Berkeley Lab through the U.S. Department of Energy Contract No. DE-AC03-76F00098.